Study of Cutoff Frequency Limits of Switchable Ferrite Microstrip Triangular Patch Antenna through Genetic Algorithm

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Abstract

The study of cutoff frequency limits of switchable ferrite microstrip triangular patch antenna through genetic algorithm is presented. In this communication we optimized cutoff frequency limits of switching region of dispersion curve obtained for LiTiMg-ferrite substrate. This dispersion curve become zero or negative under proper magnetic biasing which indicate the switch off state of microstrip antenna printed on the substrate. Within cutoff limits, zero value of propagation constant, resist the antenna as radiator without a mechanical maneuvering. The fitness functions for the GA program is developed using mathematical formulation based on nonreciprocal approach of ferrite substrate under external magnetic field. The computed results are in good agreement with the results obtained experimentally and trained artificial neural network analysis. In this ANN training Radial Basis Function (RBF) networks is used. All programming related to genetic algorithm and ANN analysis performed by MatLab 7.1

Index Terms

Microstrip Triangular Patch Antenna; Genetic Algorithm; Fitness Function; Ferrite Substrate; Magnetic Biasing; ANN Analysis Training; etc.

Introduction

In recent years there are a lot of works exercised in the microwave field with the help of artificial inelegance tool. In this microwave environment due to the recent availability of low loss, commercial microwave ferrites there is an increasing interest in the performance of the patch antennas printed on ferrite substrates. The substituted polycrystalline ferrite with DC magnetic biasing is offers number of novel magnetic and electrical characteristics including switchable and polarized radiations from a microstrip antenna. In such a case of antenna radiation, most of the power will be converted into mechanical waves and little radiates into air. Under such condition the antenna become switch off, in the sense of effectively absence as radiator.

In this work, a precise and effective approach is applied to optimize the upper limit (wU) and lower limit (wL) of cutoff frequency which is mainly responsible for the switchability of antenna. It is well known that search technique, the genetic algorithm is a parallel, robust and probabilistic search technique that is simply and easily implemented without gradient calculation, compare with the conventional gradient base search procedure. Most important of all, the GA proposed also provides a mechanism for global search that is not easily trapped in local optima. The GA proposed here an adaptive mutation rate strategy.

Genetic Algorithm

Many optimization techniques using in microwave field like hill climbing method, indirect and direct calculus based methods, random search methods etc. But Genetic Algorithm (GA) is a robust stochastic based search method that can handle the common characteristics of electro-magnetics which cannot be handled by other optimization techniques. A chromosome in a computer algorithm is an array of genes. Each chromosome has an associated cost function assigned to the relative merit. The algorithm begins with a large list of randomly generated chromosomes. Cost function is evaluated for each chromosome. Genes are the basic building blocks of a genetic algorithm. A gene is a binary encoding of a parameter. The populations which are able to reproduce best fitness are known as parents. Then the GA goes into the production phase where the parents are chosen by means of a selection process. The selected parents reproduce using the genetic algorithm operator, called crossover. In crossover random points are selected. When the new generation is complete, the

process of crossover is stopped. Mutation has a secondary role in the simple GA operation. Mutation is needed because, even though reproduction and crossover effectively search and recombine extant notions, occasionally they may become overzealous and lose some potentially useful genetic material. In simple GA, mutation is the occasional random alteration of the value of a string position. When used sparingly with reproduction and crossover, it is an insurance policy against premature loss of important notions. Mutation rates are of the order of one mutation per thousand bit transfers. According to the probability of mutation, the chromosome are chosen at random and any one bit chosen at random is flipped from '0' to '1' or vice versa. After mutation has taken place, the fitness is evaluated. Then the old generation is replaced completely or partially. This process is repeated. After a while all the chromosome and associated fitness become same except for those that are mutated. At this point the genetic algorithm has to be stopped.

Structure & Theory of Antenna

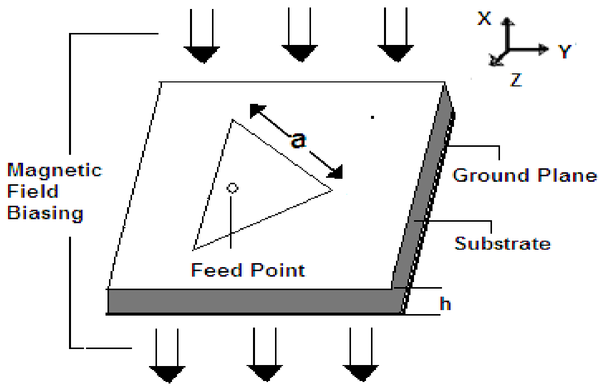

FIG. 1 SCHEMATIC DIAGRAM OF MICROSTRIP TRIANGULAR PATCH ANTENNA

Structure of microstrip triangular patch antenna is depicted in fig. 1. Here 'a' is the equilateral length of microstrip equilateral triangle patch. Patch is modeled on LiTiZn ferrite substrate of thickness 'h'. The dielectric constant and saturation magnetization ($4\pi M_s$) of substrate is 15 and 2200 Gauss respectively. It has been established that, for a biased ferrite slab, a normal incident plane wave may excite two types of waves (ordinary and extraordinary wave). In the case of normal incident magnetic field biasing ordinary wave is same as the plane wave in the dielectric slab. On the other hand, the extraordinary wave is a TE mode polarized parallel to the biasing direction with its phase propagation constant Ke.

$$K_e = \frac{w}{c}\sqrt{\epsilon_{eff} \times \mu_{eff}} \tag{1}$$

$$K_d = \frac{w}{c}\sqrt{\epsilon_{eff}} \tag{2}$$

$$\mu_{eff} = \frac{\mu^2 - k^2}{\mu} \tag{3}$$

$$\mu = 1 + \frac{w_o w_m}{w_0^2 - w^2} \tag{4}$$

$$k = \frac{w w_m}{w_0^2 - w^2} \tag{5}$$

with

$$w_o = \gamma H_o \text{ and } w_m = \gamma 4\pi M_s$$

Where H_o is the bias field, $4\pi M_s$ is the saturation magnetization, γ is the gyromagnetic ratio as $\gamma = 2.8$ MHz./Oe.

Application of Genetic Algorithm to the Microstrip Antenna and Computed Results

All the basic parameters according to fitness function, that is, applied magnetic frequency (wo), and Internal magnetic frequency (wm) are coded into 5 bit scaled binary coding. Hence the total length of the chromosome was 10 bits. The Roulette wheel selection was used for GA population. The genetic algorithm was run for 50 generations. The probability of crossover was varied from 0.7 to 0.85 and the probability of mutation was varied from 0.001 to 0.002. The fitness function expression of antenna used for optimization is:

$$[w_o(w_o + w_m)]^{1/2} < w < (w_o + w_m) \tag{6}$$
$$\text{Lower Limit} < w < \textit{Upper Limit}$$

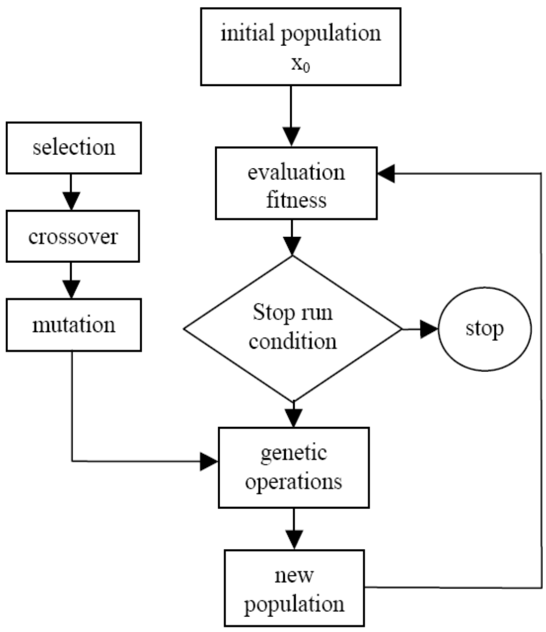

FIG. 2: FLOW CHART OF GENETIC ALGORITHM

The GA consists of five components. These are the random number generator, a fitness evaluation unit and genetic operators for reproduction, crossover and

mutation operations. The flow chart, for optimization of microstrip antenna, using GA, is shown in fig. 2.

Results and Calculations

Obtained results (table 1 and fig. 3, 4) show the variation of best, mean and expected values of cutoff frequency of antenna. The artificial neural network training program (based on RBF) also runs to optimize the cutoff frequency limits, shown in table 2. In this RBF network, the spread value was chosen as 0.01, which gives the best accuracy. RBF is tested with 100 samples frequencies but trained only for particular 20 samples frequencies. For ANN calculation by RBF differ-differ values arrange as target from literature and experimental data.

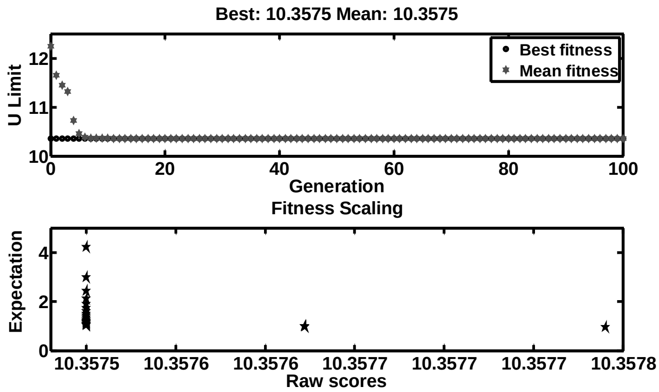

FIG. 3 VARIATION OF BEST, MEAN AND EXPECTED VALUE UPPER LIMIT OF CUTOFF FREQUENCY OF BIASED TRIANGULAR PATCH ANTENNA BY GA

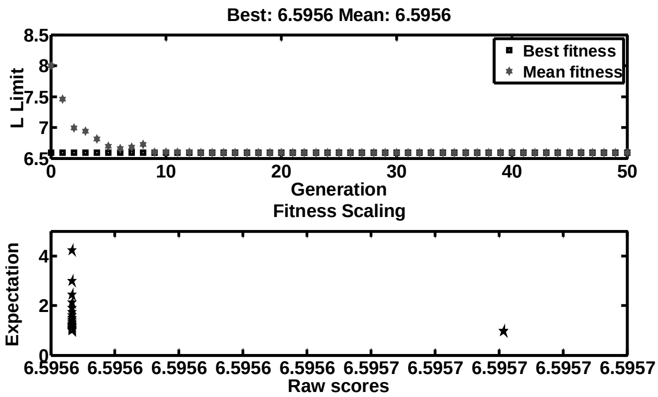

FIG. 4 VARIATION OF BEST, MEAN AND EXPECTED VALUE LOWER LIMIT OF CUTOFF FREQUENCY OF BIASED TRIANGULAR PATCH ANTENNA BY GA

Calculated values with GA program is compared with neural analysis results and experimental dispersion curve (fig. 7) which are in good agreement and given in table 3. This curve is plotted at 1550 Oe for LiTiZn-ferrite slab at SSPL Timarpur Delhi, on which microstrip patch antenna has been designed.

TABLE1: GENERATION OF FITTEST VALUE THROUGH GENETIC ALGORITHM

Pop. No.	w_o	w_m	w_L (GHz)	w_u (GHz)
1	4.2000	6.1575	6.5956	10.3575
2	4.2000	6.1575	6.5956	10.3575
3	4.2000	6.1575	6.5956	10.3575
4	4.2000	6.1575	6.5956	10.3575
5	4.2000	6.1575	6.5956	10.3575
6	4.2000	6.1575	6.5956	10.3575
7	4.2000	6.1575	6.5956	10.3575
8	4.2000	6.1575	6.5956	10.3575
9	4.2000	6.1575	6.5956	10.3575
10	4.2000	6.1575	6.5957	10.3575
11	4.2000	6.1575	6.5956	10.3575
12	4.2000	6.1575	6.5956	10.3575
13	4.2000	6.1575	6.5956	10.3575
14	4.2000	6.1575	6.5956	10.3575
15	4.2000	6.1575	6.5956	10.3575
16	4.2000	6.1575	6.5956	10.3575
17	4.2000	6.1576	6.5956	10.3576
18	4.2000	6.1575	6.5957	10.3575
19	4.2000	6.1576	6.5957	10.3576
20	4.2000	6.1576	6.5957	10.3576

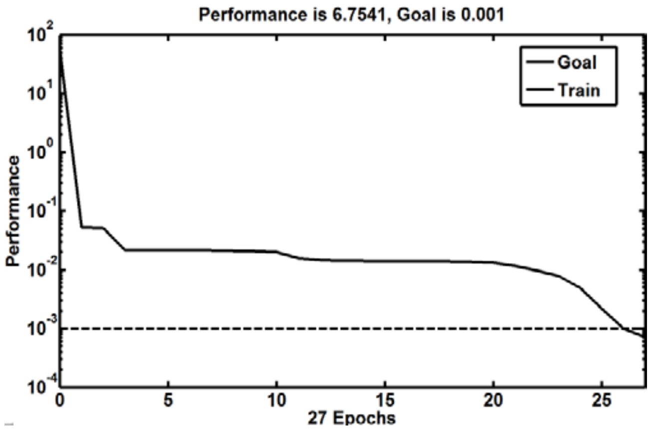

FIG. 5 TRAINING RESPONSE OF ARTIFICIAL NEURAL NETWORK PROGRAM OF OPTIMIZATION OF LOWER LIMIT OF CUTOFF FREQUENCY AT 27 EPOCHS

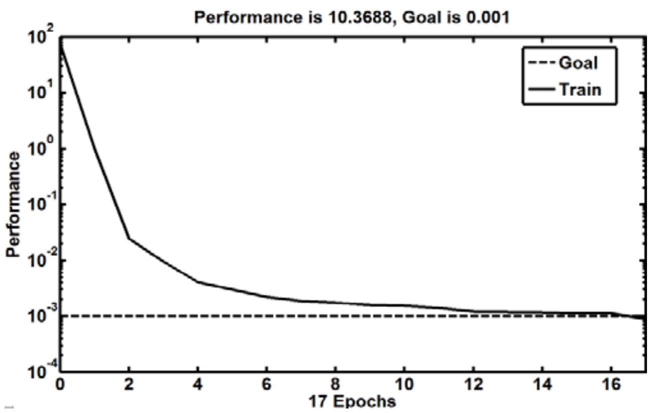

FIG. 6 TRAINING RESPONSE OF ARTIFICIAL NEURAL NETWORK PROGRAM OF OPTIMIZATION UPPER LIMIT OF CUTOFF FREQUENCY AT 17 EPOCHS

TABLE2 RESULTS OF THE ANN ANALYSIS AND COMPARISON WITH TARGET

Ordinary wave propagation constant K_d	Applied mag. freq. w_o(GHz)	Internal mag. freq. w_m(GHz)	Cutoff freq. (GHz) w_L - target	Cutoff freq. (GHz) w_L- RBF	Cutoff freq. (GHz) w_U - target	Cutoff freq. (GHz) w_U - RBF
12.50	4.2000	6.1575	6.5956	6.5963	10.3575	10.3619
12.50	4.3400	5.9816	6.6930	6.6902	10.3216	10.2769
11.50	4.3680	6.0168	6.7350	6.7294	10.3848	10.3862
12.00	4.2896	6.0520	6.6604	6.6602	10.3416	10.2886
12.50	4.2560	5.8408	6.5553	6.5353	10.0968	10.1099
11.50	4.2280	6.2279	6.6489	6.6505	10.4559	10.4234
11.00	4.3120	6.3335	6.7752	6.7689	10.6455	10.6953
10.55	4.3120	6.2631	6.7528	6.7496	10.5751	10.5901
10.00	4.2616	6.2983	6.7084	6.7126	10.5599	10.5498
12.50	4.2308	5.8408	6.5277	6.5098	10.0716	10.1459
12.50	4.2336	5.9464	6.5649	6.5566	10.1800	10.1850
11.50	4.2364	6.1223	6.6245	6.6270	10.3587	10.3676
12.50	4.2700	6.0871	6.6502	6.6520	10.3571	10.3621
12.50	4.3848	6.3335	6.8555	6.8305	10.7183	10.6737
11.55	4.3540	6.1927	6.7765	6.7638	10.5467	10.5471
11.55	4.6068	6.3335	7.0993	6.9922	10.9403	10.9414
12.55	4.0700	6.0871	6.4296	6.4056	10.1571	10.1739
11.55	4.3048	6.3035	6.7577	6.7473	10.6083	10.6138
10.55	4.3500	6.0927	6.7399	6.7371	10.4427	10.4740
10.00	4.0068	6.3005	6.4265	6.4107	10.3073	10.3054

TABLE3 RESULTS THROUGH VARIOUS TECHNIQUES AND EXPERIMENTAL WORKS.

Techniques	w_o (GHz)	w_m (GHz)	w_L (GHz)	w_U (GHz)
Genetic Algorithm	4.2000	6.1575	6.5956	10.3575
Neural Analysis	4.6368	6.3335	6.7541	10.3688
Experimental Graph	4.2000	6.1600	4.8800	10.2853

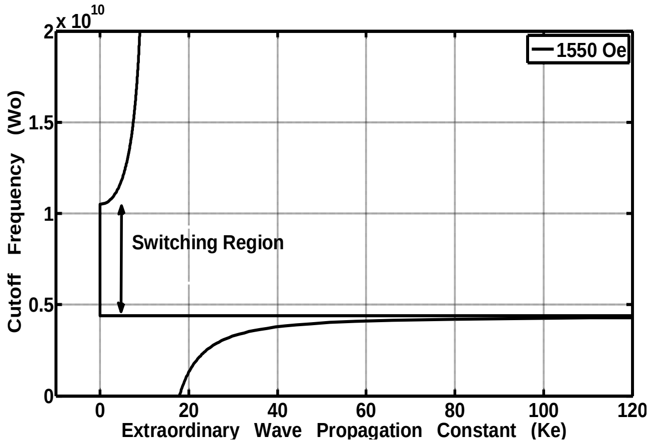

FIG. 7 DISPERSION CURVE (W VS. KE) FOR PLANE WAVE PROPAGATION PERPENDICULAR TO BIASING FIELD

Conclusion

The method of application of Genetic Algorithm to the optimization of the upper limit (w_U) and lower limit (w_L) of cutoff frequency of switchable microstrip triangular antenna printed on ferrite substrate is reported. The computed graphs and results show a good performance in comparison of ANN analysis and also have good agreement with the results obtained experimentally. Some other types of problems related to biased microstrip antennas can also optimized for the better performance by the genetic algorithm.

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